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BY THE U.S. GENERAL ACCOUNTING OFFICE

Report To The Chairman, Committee On Small Business, United States House Of Representatives

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Small Businesses Are More Active As Inventors Than As Innovators In The Innovation Process

In this report, GAO analyzes a number of studies that examine sources of invention and innovation and presents conclusions drawn from these studies about the contributions of small businesses to the innovation process. GAO concludes that small businesses have been important contributors to the innovation process and that they have been more active in invention than in innovation (actually bringing an invention to market).

While GAO was not able to generalize from the existing evidence to specify the level of small businesses' future contributions, no evidence was found to suggest that they might be less important to invention and innovation in the future than they have been in the past.

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DECEMBER 31, 1981

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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

PROGRAM ANALYSIS
DIVISION

B-201548

The Honorable Parren J. Mitchell
Chairman, Committee on
Small Business
House of Representatives

Dear Mr. Chairman:

This letter responds to your request of July 30, 1981, that we examine a number of studies that provide information about sources of invention and innovation and describe whatever conclusions can be drawn from them about the contributions of small businesses to invention and innovation. 1/ To do this, we analyzed the nine studies that are most frequently cited as support for the contention that small businesses are important contributors to the innovation process in this country. We classified those studies into three categories: studies that examine the relationship of firm size to invention and innovation; empirical studies of other aspects of invention and innovation; and reports that integrate the work of others. (The nine studies are annotated and listed by category in table 1. Detailed summaries of each study are included in appendix I.)

In this letter, we discuss the difficulties associated with interpreting these studies and present the conclusions that can be drawn from the information provided in them.

DIFFICULTIES DETERMINING THE CONTRIBUTIONS OF SMALL BUSINESSES TO INVENTION AND INNOVATION

Developing information about the contributions of small businesses to invention and innovation is difficult for two reasons.

1/Throughout this letter, we distinguish between invention and innovation. We define the innovation process in three stages, beginning with the generation of a technically feasible idea (invention), proceeding with the refinement of that idea (development), and resulting in the introduction and initial use of new products or processes in the marketplace (innovation). Hence, invention is one stage of the innovation process.

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Table 1

Studies Examining Sources of Invention and Innovation

Category I: Studies that relate firm size to invention and innovation.

CHRISTOPHER FREEMAN, The Role of Small Firms in Innovation in the United Kingdom Since 1945 (1971). This study examined the sources of innovations in the British manufacturing industry between World War II and 1970. It examined information relating to 1,100 innovations produced by 800 individual firms.

Category II: Empirical studies of other aspects of invention and innovation.

JOHN ENOS, "Invention and Innovation in the Petroleum Refining Industry" (1962). This was a study of a sample of nine major inventions in refining and cracking petroleum. The relation between the inventive idea and the innovation that was used commercially was examined.

MERTON J. PECK, "Inventions in the Post-war American Aluminum Industry" (1962). A history of 194 inventions in the aluminum industry in four technical areas of processing was analyzed to determine the economic significance of inventions.

DANIEL HAMBERG, "Invention in the Industrial Research Laboratory" (1963). This study examined the source of 45 inventions occurring between 1946 and 1955 to explore the hypothesis that large industrial research laboratories are minor sources of radically new or commercially important inventions and major sources of improvement inventions.

JOHN JEWKES ET AL., The Sources of Invention (1969). This work presents case studies of 61 inventions of commercial success or promise which occurred during 1900-68, to address the question of where and under what conditions industrial inventions arise.

GELLMAN RESEARCH ASSOCIATES, Indicators of International Trends in Technological Innovation (1976). This study examined a collection of data for 500 technological innovations introduced into the world marketplace between 1953 and 1973, to determine the relative levels of "innovativeness" of the United States, Great Britain, West Germany, France, Japan, and Canada.

WILLARD F. MUELLER, Market Structure and Technological Performance in the Food Manufacturing Industry (1979). Two periods of innovative activity in the food manufacturing industry, 1950-56 and 1967-74, were examined using separate data sets of 87 and 33 firms, respectively, to determine the sources of increases in productivity in this industry.

Table 1 (continued)

Category III: Reports that integrate the work of others, but did not collect original data.

ROBERT CHARPIE, Technological Innovation: Its Environment and Management (1967). This study was the product of an ad hoc panel investigation that considered three factors affecting invention and innovation: taxation, finance, and competition. No original data were collected.

JACOB RABINOW, Small Firms and Federal Research and Development (1977). This study is the product of an ad hoc interagency panel that examined the role and difficulties of the small firm in selling R&D to the government and in fulfilling government contractual requirements for R&D work. A literature review was conducted for this report but no original data were collected.

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First, very little empirical research has been designed specifically to determine the contributions of small businesses to the innovation process. In fact, only one of the nine studies generally cited as supporting claims about the contributions of small businesses to the innovation process had the objective of specifically examining firm size in relation to innovative output. 1/ Another work did focus on small businesses, but emphasized the "role and difficulties of the small firm in selling R&D to the Government," and not small businesses' contributions to the innovation process per se. 2/

And second, research on invention and innovation and their sources suffers from measurement and methodological problems that make interpreting research findings difficult and allow only broad generalizations to be drawn from them. There is a decided lack of adequate indicators, or measures, of the innovation process. Four indicators are generally used to measure invention or innovation--inputs to the process such as scientists and engineers employed or R&D expenditures, and outputs of the process such as patents issued or counts of inventions or innovations. Each of these indicators presents problems that challenge their validity as indicators of inventive and innovative activity.

1/Christopher Freeman, "The Role of Small Firms in Innovation in the United Kingdom Since 1945," Committee of Inquiry on Small Firms, Research report no. 6 (London: Her Majesty's Stationery Office, 1971).

2/Jacob Rabinow, Small Firms and Federal Research and Development, Ad Hoc Interagency Panel, Office of Federal Procurement Policy (Washington, D.C.: Office of Management and Budget, 1977).

Methodological problems include variation in the way small businesses are defined, problems with the size and methods of selecting samples of inventions and innovations, studies specific to only one industry and variation in the time spans examined in the research. 1/ Of these methodological problems, variation in the way small businesses are defined is of particular concern. For the studies we examined, size thresholds for small businesses ranged from 100 to 1,000 employees. While there is no generally agreed upon definition of small business, small businesses active in the innovation process are conventionally thought of to be those employing fewer than 200 people.

RESEARCH CONTRIBUTING TO KNOWLEDGE ABOUT SMALL BUSINESSES IN THE INNOVATION PROCESS

The nine studies most frequently cited as sources of support for the contention that small businesses are major contributors to the innovation process each provide us with some information about the activities of small businesses in the innovation process. However, the scope and objectives of the studies are so different that, as noted earlier, only broad generalizations can be drawn from them. It is clear, however, from the evidence examined that small businesses have been significant contributors to the innovation process. While we are not able to generalize from the existing evidence to specify the likely level of their future contributions, we found no evidence suggesting that small businesses might be less important to invention and innovation in the future than they have been in the past.

Small businesses have been important contributors to invention and innovation

All of the studies we examined provide information about the importance of the activities of small businesses in the innovation process--both in terms of the amount and significance of inventions and innovations produced. For example, one study, published in 1958, was the first major work to identify the importance of individual inventors and small businesses in invention by concluding that they had been responsible for some of the most well-known technological breakthroughs of the 20th century. 2/ In the early 1960s, another work came to a similar conclusion and reported that the bulk of the major inventions were the products of independent

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1/These measurement and methodological problems are discussed in detail in "Consistent Criteria Are Needed to Assess Small-Business Innovation Initiatives," U.S. General Accounting Office, PAD-81-15, July 7, 1981, pp. 53-55.

2/Jewkes, John, et al., The Sources of Invention, 2nd ed. (New York: W.W. Norton & Co., Inc., 1969).

inventors and small- and medium-sized firms. 1/ In 1971, the first empirical examination of the contributions of small firms to innovation was completed. It concluded that the innovative efficiency of small firms may be greater than that of large firms. 2/ In 1976, the results of an examination of the "innovativeness" of the United States, Great Britain, West Germany, France, Japan, and Canada suggested that small firms contribute a significant percentage of U.S. innovations. 3/

Small businesses have been more active in invention than innovation

Five of the seven studies that gathered data distinguish between invention (the creation of a technically feasible idea) and innovation (actually bringing an idea to the market), and provide evidence that small businesses have been more active in invention than in innovation. The other two studies did not address this conclusion.

Two of the five studies provide evidence about the contributions of small firms and individual inventors to invention. The first of these concluded that "more than one-half" of the inventions examined were the product of an individual inventor or were made "by men who were working on their own behalf." 4/ The second--through both original work and by examining that of others--concluded that only 30 percent of the inventions examined were the product of large research laboratories. This study did not specify the source of the remaining 70 percent, but concluded that the activities of small firms should no longer be neglected and ignored in efforts to foster technological innovation. 5/

Three other of the five studies provide information regarding the innovative contributions of small businesses. The first of these attributed 10 percent of post-war British innovation to small firms (under 200 employees). 6/ The second reported that 23.5 percent of innovating organizations examined were small

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1/Hamberg, Daniel, "Invention in the Industrial Research Laboratory," The Journal of Political Economy, vol. 71, no. 2 (April 1963, pp. 95-115).

2/Freeman, op. cit., p. 15.

3/Gellman Research Associates, Indicators of International Trends in Technological Innovation, prepared for the National Science Foundation (Washington, D.C., April 1976), p. 51.

4/Jewkes, op. cit., p. 73.

5/Hamberg, op. cit., p. 115.

6/Freeman, op. cit., p. 1.

businesses (under 100 employees). 1/ Finally, an examination of recipients of the Putman Food Awards found that "awards were received by corporations covering a broad spectrum of sizes, with the majority received by very small firms." 2/

Research is needed to further specify the contributions of small businesses to the innovation process

Both the nine studies we examined and a broader body of economics and innovation literature provide some information on the factors that influence the environment in which invention and innovation occur and on the activities of small businesses in the innovation process. In order to clearly understand the effect of these factors on small businesses' activities in the innovation process and to specifically determine the amount of invention and innovation contributed by small businesses--as opposed to other contributors to the innovation process--a series of carefully designed empirical studies would be required.

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At your request, we did not seek agency comments on this letter. Also, based on an agreement with your staff, we are sending copies of this letter to appropriate House and Senate committees, Representatives and Senators who have particular interest in the subject, the Director of the Office of Management and Budget, the Administrator of the Small Business Administration, the Secretary of Commerce, the Director of the National Science Foundation, and the Director of the Office of Science and Technology Policy. We will also make copies available to interested organizations and individuals, as appropriate, on request.

If we can be of further assistance to your Committee, please do not hesitate to contact us.

Sincerely yours,

Morton A. Myers
Director

1/Gellman Research Associates, op. cit., Table 3-8, p. 113.

2/Mueller, Willard F., et al., Market Structure and Technological Performance in the Food Manufacturing Industry (Madison: University of Wisconsin, 1979), p. 127.

SUMMARY OF STUDIES EXAMINED BY GAO

CHARPIE, ROBERT

Chairman, U.S. Department of Commerce Panel on Invention and Innovation, Technological Innovation: Its Environment and Management (Washington, D.C.: U.S. Government Printing Office, 1967).

Scope and objectives

This report, commonly known as the Charpie Report, was prepared by an ad hoc panel created in 1964 by the Secretary of Commerce to respond to the President's 1964 directive to explore new ways for "speeding the development and spread of new technology." On the basis of its work, the panel made a number of specific proposals aimed at improving the environment for invention and innovation. The panel's primary objective was to explore opportunities for improving the climate for technological change, with special attention to the effect of taxation, finance, and competition on invention and innovation. On the basis of its work, the panel made a number of specific proposals aimed at improving the environment for invention and innovation.

Method

This report was based on the authors' personal experience with the innovation process and data concerning R&D. No original data were collected by the panel, although studies by Enos, Hamberg, Jewkes, and Peck were examined and incorporated.

Definition of small business

Charpie uses the terms "small firm" and "small business" but does not give a precise definition. When discussing the "small company environment," he describes an "illustrative small company" in terms of a growth cycle composed of a "garage stage" when a firm is "typically less than five years old, has less than one hundred employees and less than $1 million in capital," and a "second stage business" when a firm has annual sales in the millions of dollars, more than 100 employees, and is more than five years old.

Definition of innovation

The panel describes invention and innovation as encompassing "the totality of processes by which new ideas are conceived, nurtured, developed and finally introduced into the ecomony as new products and processes; or into an organization to change its internal and external relationships; or into a society to provide for its social needs and to adapt itself to the world or the world to itself."

Conclusions

Upon examining the effects of taxation, finance, and competition on invention and innovation, the panel concluded that "independent inventors and small firms are responsible for an important part of our inventive progress, a larger percentage than their relatively small investment in R&D would suggest." However, the panel qualified this statement by acknowledging the importance of large firms to technological and economic progress and issued a challenge for both large and small firms to explore new ways of collaboration while monitoring the creative qualities of each. "From a number of different points of view, however, we are persuaded that a unique cost-benefit opportunity exists in the provision of incentives aimed at encouraging independent inventors, inventor-entrepreneurs, and small technologically based businesses. The cost of special incentives to them is likely to be low. The benefits are likely to be high." "Moreover, because a large company normally has profits against which it can offset costs, the government, in effect (through the corporate income tax), shares in 48 percent of the innovation project losses of the company. As we have seen, this is not true of a typical, small company in its early stages."

In analyzing the innovative process, the panel identified institutional and individual venture capital sources, technologically oriented universities, entrepreneurs, and close and frequent consultations among these three as elements characteristic of "the kind of total environment that seems to encourage the creation of new technological enterprises." The panel emphasized the importance of this environment by describing the difference between highly innovative industries and those which are relatively uninnovative: "the major barrier is one of attitude and environment. It is primarily a problem of education--not of antitrust, taxation, or capital availability." "By and large, the technical people who have the idea and want to build a company on it have little if any business experience and know nothing about the venture capital market. On the other hand, the sources of capital--banks, wealthy individuals, underwriters, investment trusts, and others--usually have no technical background and only rarely have available to them adequate staffs to perform the complex investment appraisals required to measure the merit of any single entrepreneurial proposal." The further assumption that "more money spent on R&D automatically has some kind of multiplier effect on innovation into the marketplace" was thoroughly discounted by the panel.

Recommendations issued by the panel were "aimed primarily at the problems encountered in the small company environment." The panel recommended various tax proposals; changes in interpreting antitrust and regulatory laws; review of government contracting policies; establishment of an overview group; a White House conference to consider the environment for innovation; and no government action establishing venture capital programs.

ENOS, JOHN

"Inventions and Innovation in the Petroleum Refining Industry," in Universities-National Bureau Conference, The Rate and Direction of Inventive Activity: Economic and Social Factors (Princeton, N.J.: Princeton University Press, 1962, pp. 299-321).

Scope and objectives

This study examined the process of innovation for nine commercial processes representing all hydrocarbon cracking innovations in the petroleum refining industry from 1913 to 1958. The objectives were to trace an innovation back to a single source in terms of its original idea and the people who conceived it, and to discuss the relation between inventions and subsequent innovations. Although this study did not consider firm size as a factor in the innovation process, Enos did arrive at conclusions relating to firm size.

Method

The author identified the nine hydrocarbon cracking innovations introduced during the period from 1913 to 1958. The author traced each innovation to its original idea and examined the relation between the inventive idea and the process of innovation both in terms of the time interval between invention and innovation, and in terms of changes in the proportions of factors that influence processing.

Definition of small business

Enos did not define small business.

Definition of innovation

Enos defined innovation as the combination of many different activities including an invention being made and recognized, capital obtained, plant acquired, managers and workers hired, markets developed, and production and distribution taking place.

Conclusions

For each of the nine successful innovations, the author found it "always difficult, if not impossible, to follow an innovation back to a single source," and that "The selection [of that source] is quite arbitrary . . ." The author states that, in four instances, "no single individual was responsible for the inventions, [for] the ideas flowed from the research departments of the innovating firms." Further, Enos reported that according to this small sample, inventors who were part of the subsequent innovation process in a firm received greater returns than inventors who did not follow their invention through to innovation.

APPENDIX I

FREEMAN, CHRISTOPHER

The Role of Small Firms in Innovation in the United Kingdom Since 1945, Committee of Inquiry on Small Firms, research report no. 6 (London: Her Majesty's Stationery Office, 1971).

Scope and objectives

The authors of this study examine the source of innovations in the British manufacturing industry from World War II to 1970. The report's objective is to adddress the debate on size of a firm in relation to innovation, invention, and research showing that the debate has been inconclusive because of the lack of adequate empirical evidence on the relative contribution of small firms to innovation. The report provides a number of conclusions regarding the activities of small firms as innovators.

Method

A preliminary list of 1,300 innovations in the British manufacturing industry occurring between 1945 and 1970 were identified and classified as product innovations, process innovations, material or component innovations, and management innovations. These innovations could be attributed to about 800 different firms. Each firm associated with one or more innovation was requested to confirm whether it had in fact made the innovation, to check the dates of innovation, and to supply information on their employment size and ownership at the time of the innovation. The response rate was about 90 percent, providing information on over 1,200 innovations. One hundred of these innovations were not used because of inadequate information.

Definition of small business

Freeman defines a "small firm" as one with fewer than 200 employees.

Definition of innovation

Innovation is defined as "the first commercial introduction of a new product, process, or system in British industry." Freeman makes the point that an invention or a patent is not an innovation.

Conclusions

The contribution of small firms to industrial innovation in Britain since World War II was found to be "less than their share of total employment or their share of net output, but higher than their share of R&D expenditures." Freeman reports that small firms accounted for 10 percent of post-war British innovations. These innovations were concentrated mainly in a few industries, principally scientific instruments, electronics, and machinery.

The small firms made little or no contribution to innovation in industries of high capital intensity.

According to Freeman, the evidence shows that the vast majority of those small firms do not perform any organized R&D, and that their share of total industrial R&D expenditures is probably less than 5 percent. Freeman explained "this evidence is not conclusive for the debate on innovation for three reasons: (1) It can be shown from case histories that some important innovations have been launched with negligible or very low R&D expenditures. (2) Even though total R&D expenditures by small firms may be relatively small by comparison with output, this does not exclude the possibility that a few small firms may be highly research-intensive and contribute some extremely important innovations. (3) R&D statistics generally related to an organized and separately distinguishable activity within the firm. The absence of a separate R&D or technical department within the firm may lead to under-reporting of development activities in the smaller firms. Inventive and innovative work may be undertaken by engineers, technicians, managers, and workers outside any formal R&D structure on a part-time basis. Such work is likely to be particularly important in the smaller firms because of the generally lower degree of functional specialization."

Freeman states that "the evidence from patent statistics suggests that the contribution of small firms to inventive output is somewhat greater than their share of R&D expenditures might indicate. If numbers of patents are taken as being broadly indicative of inventive achievement, then there is fairly strong evidence that in the United States at least, small firms' share of inventions is substantially higher than their share of R&D."

In general, Freeman suggested that the results of his survey "confirm the view of those economists who suggested that the innovative efficiency of small firms may be greater than that of large firms, in the sense that they apparently produce more innovations per [dollar] of R&D expenditure than their larger competitors."

GELLMAN RESEARCH ASSOCIATES

Indicators of International Trends in Technological Innovation, prepared for the National Science Foundation, Directorate for Scientific, Technological, and International Affairs, Division of Science Resources Studies (Washington, D.C., April 1976).

Scope and objectives

This study, commonly known as the Gellman Report, was an empirical exploration of the relative levels and character of innovative activity in several countries. The objective of the study was to provide data to the Science Indicators Unit of the National Science Foundation to compare the relative "innovativeness" of the the United States, Great Britain, West Germany, France, Japan, and

Canada. The authors presented a number of findings, among them, comparison of the contributions of small firms to innovation in the countries examined.

Method

This study examined 500 technological innovations introduced into the world marketplace between 1953 and 1973. The innovations were selected by an international panel of experts from the six countries from an original list containing 1,310 innovations obtained from the trade literature. The distribution of the 500 innovations ultimately studied was: United States, 63 percent; United Kingdom, 17 percent; Federal Republic of Germany (West Germany), 7 percent; Japan, 7 percent; France, 4 percent; and Canada, 2 percent.

Definition of small business

The authors implicitly define "small and medium-sized firms" as having fewer than 1,000 employees. Firm size is also discussed in terms of dollars, with a "small firm" being one with annual sales of up to $5 million.

Definition of innovation

Innovation is discussed in terms of bringing an invention of technology to the market.

Conclusions

For the U.S. innovations examined, small- and medium-sized firms were found to have maintained the same level of innovative activity as large firms. Small firms in the United States were more active in innovative activities and more likely to achieve growth than the small firms in the other countries studied. The Gellman data showed that over the 21-year period covered by the study, 47.3 percent of the innovating organizations in the United States had fewer than 1,000 employees and 23.5 percent had fewer than 100 employees.

HAMBERG, DANIEL

"Invention in the Industrial Research Laboratory," The Journal of Political Economy, vol. 71, no. 2 (April 1963, pp. 95-115).

Scope and objectives

This study examines the sources of both major and minor inventions. The objective of this work was to explore the hypothesis that the large industrial laboratory is likely to be a minor source of major inventions; rather they are likely to be a major source of improvement inventions. The author performed an extended analysis of some of the apparently important factors that lend support to the hypothesis. Based on his findings, the author

recommended that future efforts to foster technological progress focus on small- and medium-sized firms.

Method

This study is based on a sample of major inventions which occurred during the decade from 1946 to 1955. At the time of this study, the author had investigated 27 of a total of 45 major inventions. This was not a random collection in a statistically meaningful sense, according to Hamberg.

Definition of small business

The author uses the term "small firm" but offers no definition.

Definition of innovation

Invention, not innovation, is examined in this study. Hamberg does not define invention per se but distinguishes two kinds: (1) major inventions ("radically new and commercially or militarily important"), and (2) minor or improvement inventions. The cumulative effects of these improvement inventions may be, and often have been, of substantial importance over long periods of time for advancing technology, investment opportunities, and economic growth. Most of the improvement inventions are not likely to involve radically new inventive activity.

Conclusions

Based on his own work and by examining other studies of inventions (Grosvenor, Hatfield, Jewkes, Mueller, Peck, Hamberg, and Enos), Hamberg reported that all of the studies found fewer than 30 percent of "important" inventions to be the product of the research laboratories of large companies. He did not find any other study of inventions that provided contrary evidence. Evidence set forth in his report suggests that there are inherent incompatibilities between the large industrial laboratories and high-level inventive achievement.

After presenting the results of his analysis, the author concluded with comments on fostering innovation: "In some cases by design, in others by administrative expediency, policies bearing on the inventive process have had the effect of promoting the institutionalization of invention in the large industrial laboratories." The author emphasized that future efforts to foster technological progress must not neglect but develop ways of supporting the work of independent inventors and small- and medium-sized firms. The author continued, stating that "without any careful consideration, the laboratories of the large industrial corporations have been receiving all the accolades and most of the support. Although it appears that the bulk of major inventions originate outside these laboratories, particularly in the work of independent inventors and small- and medium-size firms, these

sources have been relatively neglected and their potential contributions virtually ignored--at least in our formal policies. It seems clear that future efforts to foster technogical progress must cease this neglect and develop ways of supporting these wellsprings of fundamental advances in the arts."

JEWKES, JOHN, DAVID SAWERS, AND RICHARD STILLERMAN

The Sources of Invention, 2nd edition (New York: W.W. Norton & Company, Inc., 1969).

Scope and objective

This study is one of the most widely quoted, and was a major effort to accumulate facts and make some contribution to a better understanding of the dynamics of the economic system. The objective of this work was to "throw some light upon at least one fragment of such vast and intricate matters [as inventiveness] by asking what seems at first sight a simple and direct question: where and under what conditions have industrial inventions arisen in modern times?" Jewkes et al. provided many observations and conclusions regarding both inventiveness and R&D activities of organizations and individuals.

Method

Sixty-one inventions of commercial success or promise of public value which occurred between 1900 and 1968 were selected as case studies to examine industrial invention. This work is the second edition of an original study which examined 51 invention case histories originating during the 1900-58 period. This edition added 10 other recent cases which occurred between 1958 and 1969. The authors emphasized that the choice of what was regarded as "important" inventions was largely arbitrary, not in any sense a scientifically balanced sample.

Definition of small business

When referring to firm size categories for purposes of R&D, the authors used the term "small business" to mean those firms with fewer than 500 workers.

Definition of Innovation

Jewkes et al. do not define innovation; however, they make a distinction between invention and development. "Invention is the stage at which the scent is first picked up, development the stage at which the hunt is in full cry." "Development is the stage at which the task to be performed is more precisely defined, the aim more exactly set, the search more specific, the chances of final success more susceptible to measurement than is true at the stage of invention."

Conclusions

The many conclusions included in this work can be grouped into two categories: R&D activities and innovativeness. The following excerpts are from the report's conclusions about R&D activities:

--"The greater part of industrial research is conducted by a few very large firms. About one-half of the industrial research and development workers in the United States are found in the 70 or 80 largest firms."

--"The generalization is that for [the] manufacturing industry as a whole, and for the major industrial groups separately, research and development on some scale is more frequently found among larger firms than smaller. Firms employing more than 5,000 workers, it is virtually true to say, all do research and development; only one in ten of the firms employing less than 500 workers do so; there is a steady gradation between these limits."

--"Although small firms are less likely to spend money on research and development than large, when they do in fact engage in these activities, firms in the low-size groups appear to spend, on the average, in proportion to their size, as much as firms in the large-size groups."

Conclusions regarding firm size that fall under the heading of innovativeness are:

--"It is difficult to see any simple or consistent relation between the size of the firm and its inclinations to engage in research in the hope of producing innovations."

--"The smaller firms may be deterred from research because even if it fell upon some invention of real value it might not be able to afford the cost, or face the many other complexities, of development and marketing."

--". . . there is substance in the argument that, given the strong element of chance in invention, the larger firm can better afford to carry the costs of the numerous, inevitable failures with the proceeds of a few sporadic successes."

--Of the 61 cases studied in detail in this work, "successful development [of inventions] appears to have been carried out by individuals or smaller firms without enormous cost in [development expenditure]."

--"More than one-half of the cases can be ranked as individual invention in the sense that much of the

pioneering work was carried through by men who were working on their own behalf without the backing of research institutions and usually with limited resources . . . ."

--"The small firm may have the will to innovate; its birth, survival and growth may often depend upon the exploitation of a new idea, but it may lack the power to innovate because it cannot find sufficient capital."

--"[T]he extent to which a firm will embark on development depends upon many factors other than its size."

--"It can no longer be claimed that . . . success in invention and development will inevitably go to the larger firms with the larger research organizations when it is becoming increasingly apparent in the United States that small research firms, such as those found on 'Route 128' backed by appropriate financial agencies are a most fertile source of technical innovation."

MUELLER, WILLARD F., ET AL.

Market Structure and Technological Performance in the Food Manufacturing Industry (Madison: University of Wisconsin, 1979).

Scope and objectives

This study examined increases in productivity in the food manufacturing industries. The objective of the study was to explain the sources of increased productivity in these industries by examining the relationship between the competitive structure of these industries and their R&D investments and outputs, and by identifying the origins of inventions and innovations influencing productivity in these industries. While most of the conclusions of this research had to do specifically with industrial structure, the study did find that small businesses made important innovative contributions in the food manufacturing industry.

Method

Two periods of innovative activity in the food manufacturing industry (1950-56 and 1967-74) were examined in this study. In Part I of this report, 51 firms (chosen from a sample of firms reporting to the Securities and Exchange Commission) were used to obtain R&D expenditure data. Information on an additional 120 firms chosen from 1,000 reporting to the Federal Trade Commission and several other sources--a study for a House subcommittee, an unpublished data appendix, and "from a variety of public sources" --were used to obtain structural data. For Part II, on patents, "6 important food manufacturing industries" were used to identify the origins of patents covering various types of apparatus and machinery. Also in Part II, a total of 245 Putman Food Award

recipients during 1969-76 provided information relating to 265 food manufacturing innovations. The Putman Food Awards are given by the editors of Food Engineering "to recognize major advances which have had significant contributions to more efficient and effective operation of the food processing industries."

Definition of small business

Mueller does not provide a definition of a small business, but states "The size of the firm, measured in various ways, is the most popularly tested variable in the literature on firm invention and market structure." In Part II, the size distribution of Putman Award recipients was characterized by Mueller as "very small firms . . . with sales below $10 million" and "modest-sized firms . . . with sales of $11 million to $100 million."

Definition of innovation

Mueller provided a definition of innovation by Scherer. 1/ "Innovation involved the entrepreneurial functions required to carry a new technical possibility into economic practice for the first time--identifying the market, raising the necessary funds, building a new organization, cultivating the market, etc."

Conclusions

In this study, Mueller reported that there appeared to be a "large number of reasons to expect the costs of inventions to fall as the size of the firm increases." From the data selected for this investigation as sources of inventions, "the great majority (90 percent) of mechanical inventions . . . originated outside the industries. Of the 10 percent originating within the industries, less than one-half originated within the four leading firms in each industry."

Mueller states that "[T]he most striking feature of the size distribution of Putman Award recipients is that awards were received by corporations covering a broad spectrum of sizes, with the majority received by very small firms."

Mueller adds that "another finding is the great diversity of the sources of total inventive and innovative activity. Firms of all sizes within and outside the food manufacturing industries, individual inventors, independent research laboratories, and government-sponsored research laboratories have all made meritorious inventions. Smaller enterprises have been especially productive in this regard."

1/F. M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally, 1970, p. 350).

PECK, MERTON J.

"Inventions in the Post-War American Aluminum Industry," in Universities-National Bureau Conference, The Rate and Direction of Inventive Activity: Economic and Social Factors (Princeton, N.J.: Princeton University Press, 1962, pp. 279-298).

Scope and objectives

This study is a history of inventions in the aluminum industry from 1946 to 1957. The objective of this work was to study the "significance of various inventions in advancing the state of the art." This study investigated the sources of inventions in the aluminum industry and addressed the relationship of oligopoly and monopoly to the rate of inventions, and provides conclusions regarding both.

Method

A sample of 194 inventions in four technical areas of the aluminum industry (joining, finishing, fabricating, and alloys) from 1946 to 1957 were examined. These inventions were selected from "a survey of inventions reported in the trade press and compiled by the author." "The standard for novelty [in selecting inventions] is low. It suffices if an invention is described as an advance in the state of the art in either the trade paper of the industry, Modern Metals, or another trade publication." "The inventions so recorded will vary widely in terms of their novelty and economic significance."

Definition of small business

The author provides no specific definition of small business but uses relative comparisons such as "secondary aluminum producers and independent fabricators are individually small compared to the primary producers," and "extruding is largely a small business field containing firms with assets of as little as $200,000."

Definition of innovation

"Innovation," per se, is not discussed. Rather the author examines "invention" and defines it as the introduction of a new product or product technique.

Conclusions

Because Peck did not consider firm size as a variable in his analysis of aluminum industry inventions, no specific conclusions concerning small firms were given. However, the author did make some relative comparisons between firms within the aluminum industry. Peck reported that the equipment makers, "which are relatively small in their market compared to some of their customers and to all the primary producers," were the major source of

inventions in three of the four technical areas studied. With regard to the question concerning the rate of invention, Peck observed that "oligopoly is often considered more conducive to invention than monopoly simply because of the greater number of independent decisions and approaches."

RABINOW, JACOB

Small Firms and Federal Research and Development, Ad Hoc Interagency Panel, Office of Federal Procurement Policy (Washington, D.C.: Office of Management and Budget, 1977).

Summary

This study, commonly referred to as the Rabinow Report, is the product of an ad hoc interagency panel which consisted of officials from the National Bureau of Standards, the National Aeronautical and Space Administration, the Department of Defense, the Energy Research and Development Administration, the Small Business Administration, the National Science Foundation and the Office of Management and Budget. The objective of the panel was to examine the role and difficulties of the small firm in selling R&D to the government and in fulfilling government contractual requirements for R&D work. The panel arrived at a number of conclusions upon which they based recommendations for Federal action.

Method

This report was based on a literature search and synthesis of approximately 75 documents. No original data were collected.

Definition of small business

A small firm was defined as one with fewer than 1,000 employees.

Definition of innovation

Innovation was defined as a process consisting of research, development, production, marketing, and distribution.

Conclusions

The Rabinow Report cited a number of findings which were taken from other studies. The independent conclusions of the panel focused on firm size as a factor in Federal R&D contracting. The primary finding was that "A significant portion (64 percent) of Government R&D is for development normally involving large industrial firms," showing that "The percentage of both total expenditures for R&D and R&D contract awards to small firms are very low." The panel attempted to explain this observation by comparing the characteristics of small and large firms in terms of advantages and disadvantages of each in performing R&D work. The panel suggested that "On a competitive basis, large firms have a

greater capability to determine what the Government is interested in researching and to unravel the complexities of 'Requests for Proposals' for R&D work." "Preparation of proposals is expensive and time-consuming to a point frequently exceeding the capabilities of small firms." Finally, the panel reported that "A bias in favor of large firms can exist when awarding R&D contracts. The tendency is to consider awards to large well-established firms 'safer' than to small firms."

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